



www.ohspecialist.com

SARS-CoV-2 & Air Disinfection

UVGI (ultra-violet germicidal irradiation)

29 July 2021
Dr Greg Kew
Occupational Medicine Specialist

South African Facilities Management
Association (SAFMA)



▲ Ventilation

- Natural ventilation
- Mechanical ventilation

▲ Isolation / enclosure

▲ Disinfection

- Ultraviolet Germicidal Irradiation (UVGI)
- Room air cleaners



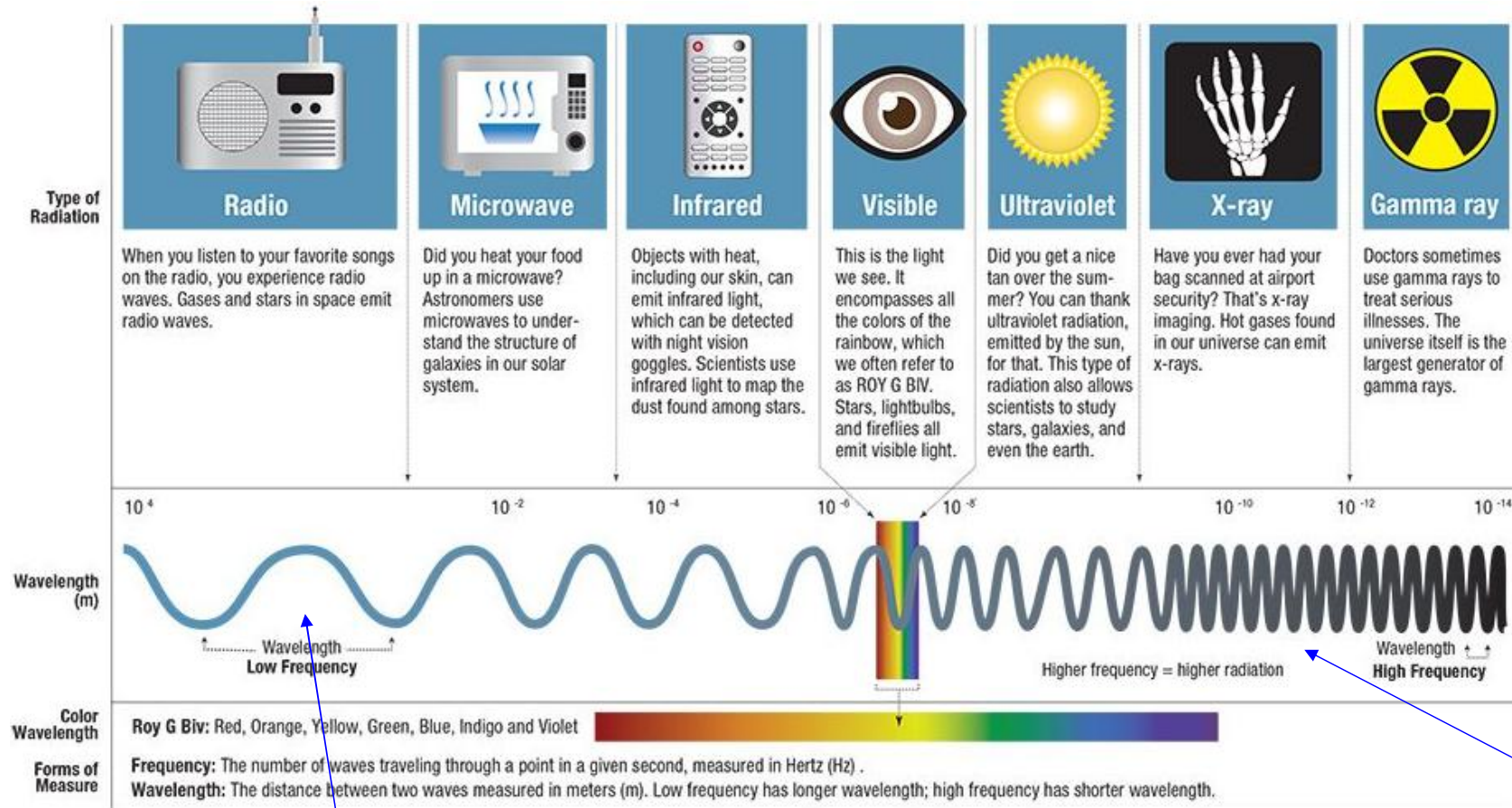
- ▲ What is ultraviolet light (UV-A / UV-B / UV-C??)
- ▲ How does it “disinfect”?
- ▲ How effective is it? Does it work for SARS-CoV2?
- ▲ Is it safe?
- ▲ How is it applied / used?
- ▲ Limitations of use

What is “Ultraviolet Radiation”?



- ▲ “Radiation” is energy that moves in the form of waves
- ▲ “Light” is a form of “radiation” – such as sunlight
- ▲ The light waves (radiation) we can see are called “visible” light”
- ▲ Visible light is made up of waves of varying wavelength, which give the various colours that we see

Ultraviolet light & the “electromagnetic spectrum”



Radiation waves also occur in nature in forms other than visible light, determined by varying wavelengths - from narrow wavelengths (x-rays) to wide wavelengths (radio)

- ▲ These various types of radiation are very familiar to us – we encounter them every day!
- ▲ Ultraviolet light is the part of this spectrum - just beyond visible violet light

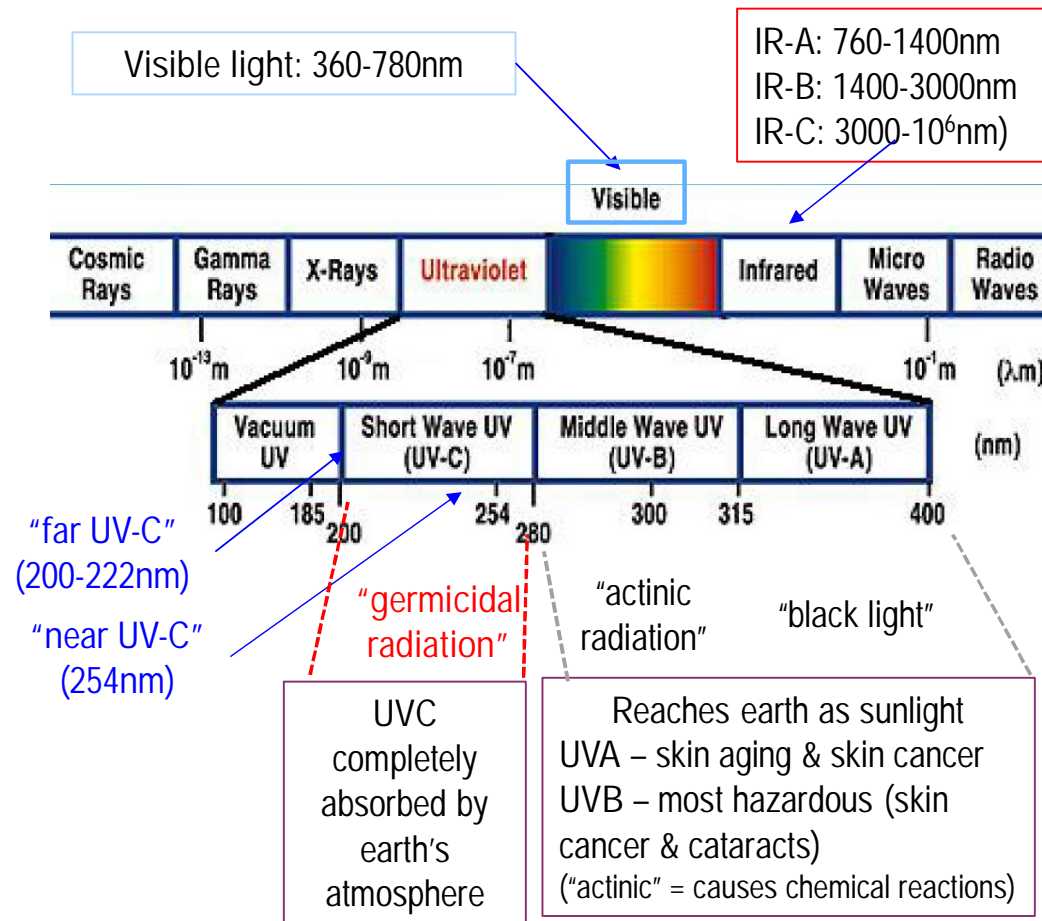
Ultraviolet Light & “Germicidal Irradiation”



- ▲ In the early 1930's, the ultraviolet part of the spectrum was divided into 3 “**Spectral Bands**”: UV-A, UV-B, UV-C, by the International Commission on Illumination (“CIE”) Committee on Photobiology
- ▲ A 4th band was added later – “vacuum UV”
- ▲ **UVC** (200-280nm) is the germicidal band (capable of neutralising germs) => “**UVGI**”
- ▲ Most common germicidal wavelength used = **254nm** (“**near UV-C**”)
- ▲ The shorter wavelengths **100-222nm** (“**far UV-C**”) – safer to humans (do not penetrate outer layer of skin / liquid film of eyes) but are also germicidal.
- ▲ The energy content (“dose”) of UV light is measured in millijoules per cm² (**mJ/cm²**)
- ▲ The *intensity* of the energy delivered is measured in milliwatts per cm² (**mWatts/cm²**) (watts = joules/second)



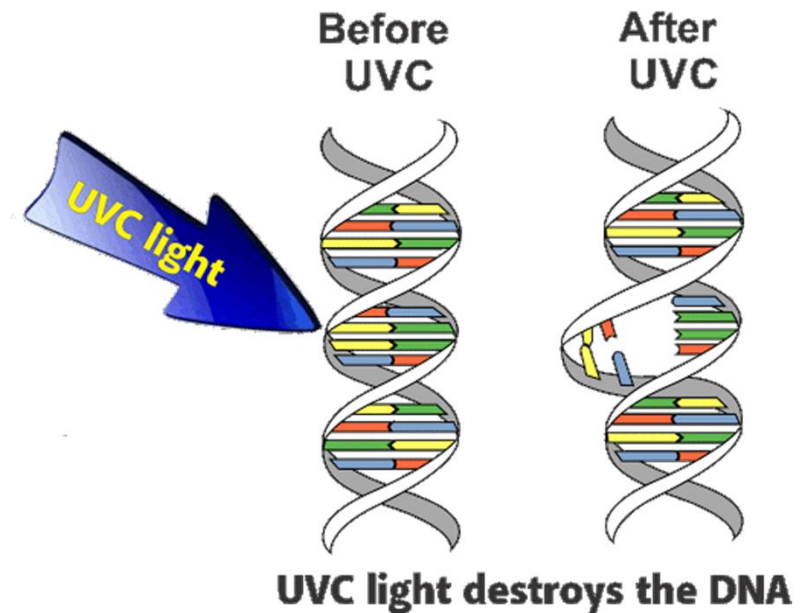
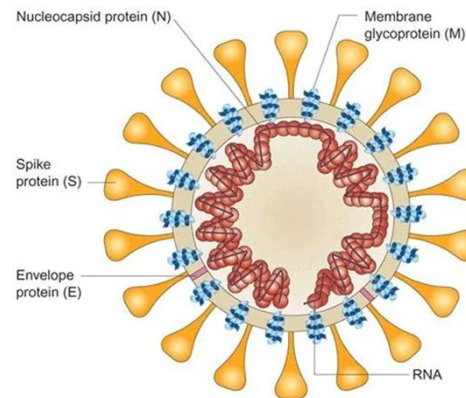
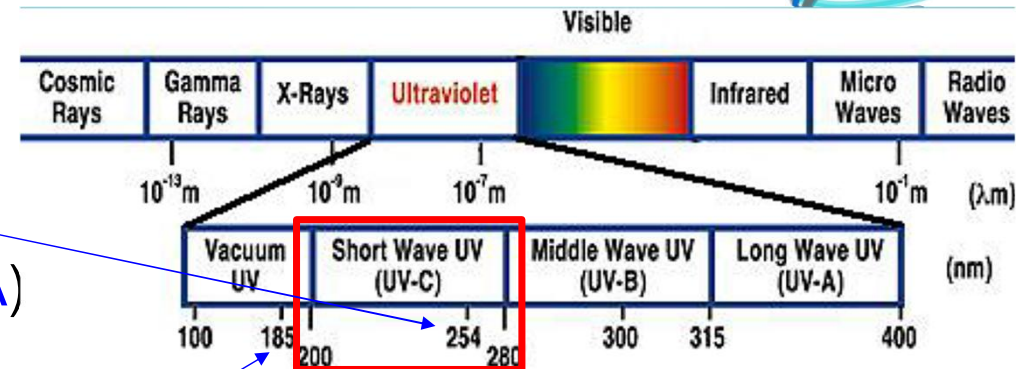
International Commission on Illumination
Commission Internationale de l'Éclairage
Internationale Beleuchtungskommission



How does it disinfect?



- ▲ UV light at 254nm damages the micro-organism's genetic material (RNA or DNA) microorganism cannot replicate
- ▲ UV light at 200-222nm damages the viral surface proteins needed to attach to human cells (where it penetrates viral coating, it also damages RNA & DNA)



How effective is UVC light as a “germicide”?

- ▲ UVC - very effective! (BUT note - UVA & UVB are not effective)
- ▲ In **1903**, Niels Finsen won the **Nobel Prize** for discovering that UV light kills germs.
- ▲ In **1942** Wells published research on its effectiveness in preventing measles in schools
- ▲ In **1946**, Matthew Luckiesh published a monograph on its use
- ▲ Despite proven efficacy, has remained unpopular - eclipsed by the discovery of antibiotics, and fear of effects of skin & eyes (& cancer).
- ▲ Many studies have been done to demonstrate its effectiveness in healthcare settings – usually against **TB**.
- ▲ Many UVC installations in public health clinics across SA.
- ▲ Effectiveness of UVC 245nm and UVC 222nm against **SARS-CoV2** has been researched and published. A kill dose of 3.7–10.6mJ/cm² has been proposed*.

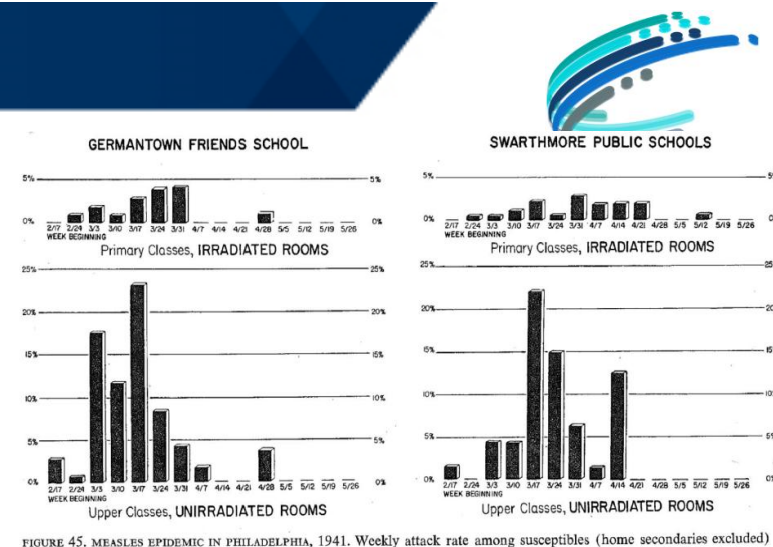
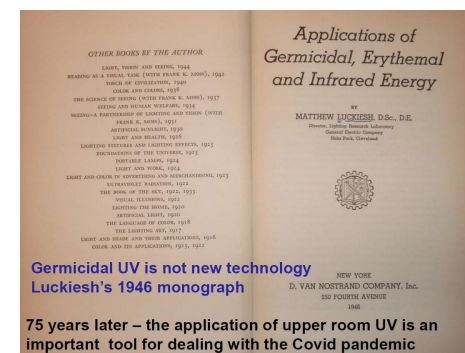


FIGURE 45. MEASLES EPIDEMIC IN PHILADELPHIA, 1941. Weekly attack rate among susceptibles (home secondaries excluded)



Germicidal UV is not new technology
Luckiesh's 1946 monograph

75 years later – the application of upper room UV is an important tool for dealing with the Covid pandemic

UV-C lethal doses for SARS-CoV-2. **

Viral inactivation (%)	UV-C dose (mJ/cm ²)	Exposure time (s)
90	0.016	0.01
99	0.706	0.32
99.9	6.556	2.98
99.99	31.880	14.49
99.999	108.714	49.42

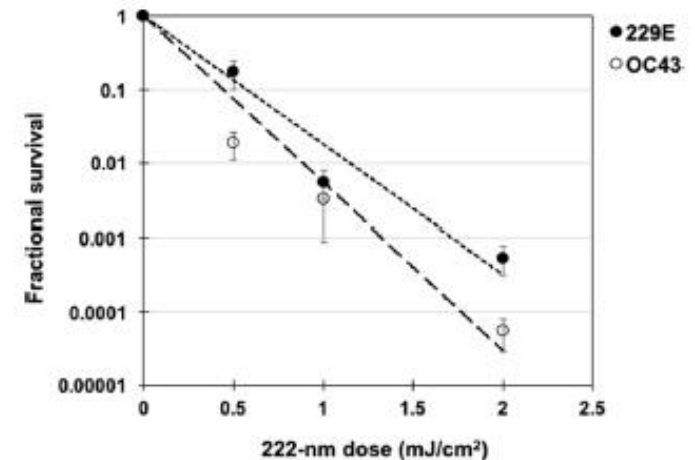
* Hessling et al, Ulm, Netherlands. GMS Hygiene & Infection Control. Vol 15: 2020.

** Sabino & Sellera, et al (Eslevier, Sep 2020)

How effective & safe is “far UV-C” as a germicide?



- ▲ Buonanno et al (published in *Nature Research*, 24/06/2020)
- ▲ (lab setting, aerosolised human coronavirus)
- ▲ Findings: continuous exposure at the regulatory exposure limit would result in:
 - 90% viral inactivation in ~8minutes
 - 95% in ~11minutes
 - 99% in ~16minutes and 99.9% inactivation in ~25minutes
 - (even levels as low as 1.2-1.7mJ/cm² can be used)
 - **Conclusion: Effective!**
- ▲ Safety of continuous exposure: far UVC light is strongly absorbed by proteins, so ability to penetrate into biological materials very limited (eg the skin, even the liquid film over the cornea of the eye).
- ▲ Therefore researchers like Buonnano argue for the continuous application of far-UVC in public settings.



What health & safety concerns with UVGI



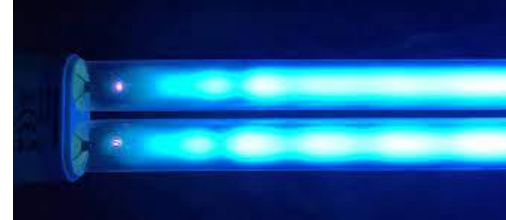
- ▲ Direct exposure of skin and eyes to UVC at **254nm** may cause painful **eye injury** (photokeratitis & conjunctivitis or “arc eye”) and **burn-like skin reactions** (even brief direct eye contact)
- ▲ UVC at **222nm** is unable to penetrate into biological materials (eg first layer of cells of the the skin, even the liquid film over the cornea of the eye) => very safe
- ▲ Some UVC lamps generate **ozone**. Ozone inhalation can be **irritating to the airways**. (ozone generation avoidable by using titanium-doped quartz glass)
- ▲ Some UVC lamps contain **mercury** (caution during clean-up if a lamp breaks)
- ▲ UVC can degrade certain materials, such as plastic, polymers, and dyed textile.
- ▲ The risk of *cancer* relates to the *presence of UVB* light which can be in the beam generated by the equipment
- ▲ Safety related to **UVC** depends on **wavelength** (254nm vs 222nm) & **dose**, (dose = intensity x duration) of exposure
- ▲ The recommended **exposure limit** is 6 mJ/cm². (0.2μW/cm² over 8 hours) (W=J/s)

Types of UV lamp



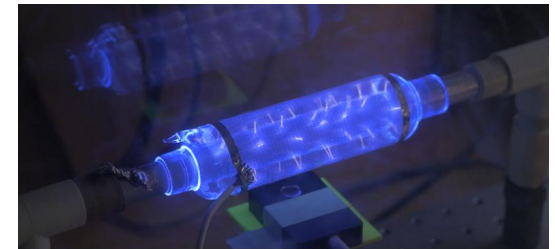
▲ Low-pressure mercury lamp

- most common format
- main (>90%) emission at 254 nm
- mercury is a health concern (maintenance, waste)



▲ Excimer lamp or Far-UVC lamp

- peak emission of around 222 nm (“far UVC”)



▲ Pulsed xenon lamps

- short pulses of **broad** spectrum (including UV, visible and infrared) light have been filtered to emit mainly UVC radiation
- generally used where there are no people (surfaces in hospital operating rooms, etc)



▲ Light-emitting diodes (LEDs)

- emit a very **narrow** wavelength band of radiation
- peak wavelengths at 265nm, 273nm, and 280nm, among others

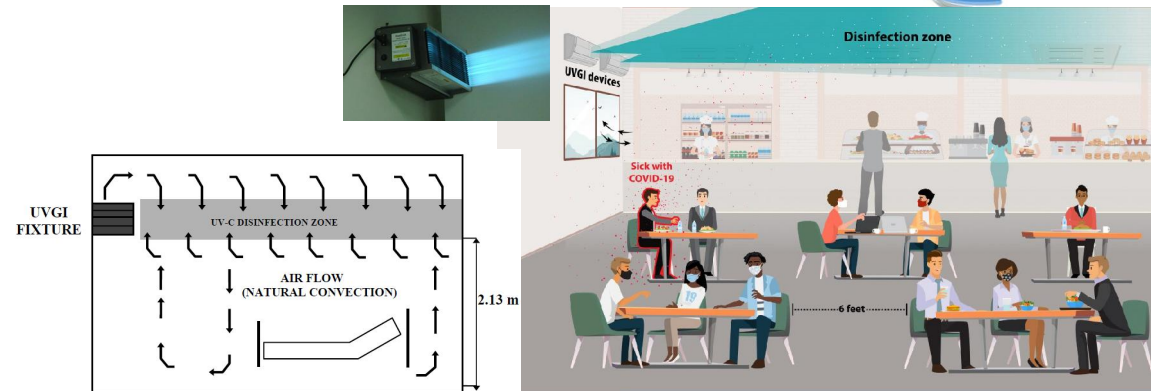


How is it used?



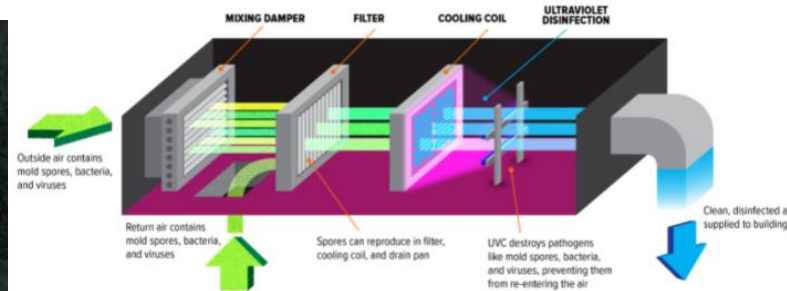
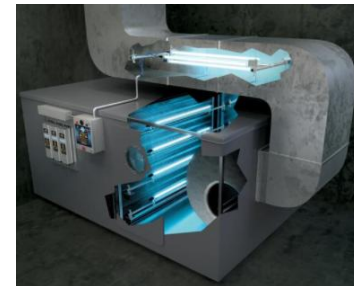
▲ Whole – room radiation

- Unoccupied: operating theatres, busses, airplanes, etc
- Occupied: far-UVC (?)



▲ Targeted Radiation

- “Upper-room” UVGI
- Enclosed
 - In the building’s ventilation ducting
 - Disinfection cabinets (sterilizing surgical instruments)
 - Installed in room “air cleaners / purifiers”



Limitations of use



- ▲ Requires direct “line of sight” (NB: avoid “shadows”)
- ▲ Requires adequate dose (contact time & radiation intensity). NB: correct installation
- ▲ Cannot penetrate through dust (dust on globe, dust on surfaces) – NB: maintenance schedule
- ▲ Intensity drops over time – must be replaced – NB: maintenance schedule
- ▲ Intensity drops over distance. NB: correct installation
- ▲ Can have health & safety effects (ozone, eye burns). NB: quality of equipment & correct installation
- ▲ Note: when installed in the ventilation ducting, it does not reduce the exposure in the room, it just improves the viral-reducing efficiency of the filters in the ventilation system
- ▲ Caution: UV “Air purifiers” can be misleadingly marketed. They do kill virus, but their ability to clear real-world room is limited (small fans). So you need a lot to achieve adequate disinfection. As for an independently certified “Clean Air Delivery Rate” (CADR)



- ▲ UVGI is effective at neutralising biological agents (influenza, TB, SARS-CoV2)
- ▲ To be effective it must be installed & maintained correctly
- ▲ It does not replace ventilation as a control - it supplements it
- ▲ UVGI is relatively inexpensive and can save money by reducing the ventilation demands

Useful references

ISBN 978-0-626-34006-3

SATS 1706:2016

Edition 1

SABS STANDARDS DIVISION

Technical specification

UVGI luminaires — Safety and performance requirements



UVGI disinfection technology (A brief overview)

(ASHRAE*) CHAPTER 17

ULTRAVIOLET LAMP SYSTEMS

<i>Terminology</i>	17.1
<i>UVGI Fundamentals</i>	17.2
<i>Lamps and Ballasts</i>	17.3
<i>Maintenance</i>	17.7
<i>Safety</i>	17.7
<i>Unit Conversions</i>	17.9

*American Society of Heating, Refrigerating and Air-Conditioning Engineers

IMPLEMENTATION of UPPER ROOM UVGI - AN ABRIDGED GUIDE

Rev 6, Jan 2019

Tobias van Reenen¹, Tanusha Singh², Peta de Jager¹, Mladen Poluta³, Anton Stoltz⁴

1) Council for Scientific and Industrial Research, 2) National Institute for Occupational Health, 4) University of Cape Town 4) University of Pretoria

UVGI DISINFECTION OF ROOM AIR: AN EVIDENCE BASED GUIDELINE FOR DESIGN, IMPLEMENTATION AND MAINTENANCE

DISCUSSION DRAFT

Rev 6.1

AUTHORS:

Tanusha Singh (NIOH) (Chair)

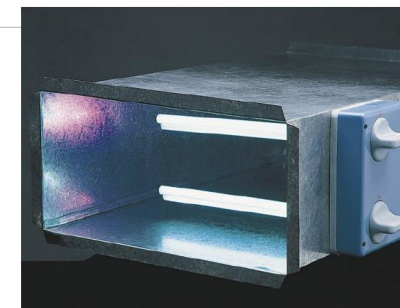
Peta de Jager (CSIR)

Mladen Poluta (University of Cape Town)

Tobias van Reenen (CSIR)

Anton Stoltz (University of Pretoria)

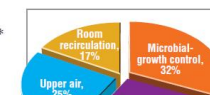
UVGI Design Basics



for Air and Surface Disinfection

**Ultraviolet germicidal irradiation lamps
can help clean coils and improve
indoor air quality**

By W.J. KOWALSKI, PE, and
WILLIAM P. BAHNFLETH, PhD, PE,*
Department of Architectural
Engineering,
The Pennsylvania State University,
University Park, Pa.



promise that the elimination of air-borne disease seemed possible. In 1936, Hart used UVGI to sterilize air in a surgical operating room.² In 1937, the first application of UVGI for a school ventilation system dramatically reduced the incidence of measles, with subsequent applications enjoying similar success.³ Experiments by Riley and O'Grady⁴ resulted in the elimination of tuberculosis (TB) bacilli from hospital-ward exhaust air.

A plethora of designs that were more imitative than engineered followed



Thank you for your attention!